



STABILIZATION OF EXPANSIVE SUBGRADE OF PAVEMENT BY USAGE OF VITRIFIED POLISH WASTE AND GEOGRID PROVISION

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ABSTRACT

Black cotton soils or expansive soils which are vastly found in India are known for their susceptibility to varying moisture condition. This causes severe problem for pavement construction in areas where black cotton soils are predominantly present. To cope up with this problem in many sites, soil replacement technique is adapted which is very costly. In present investigation a study area from Samalkot to Uppada in Andhra Pradesh, India is selected having similar problem. Experiments are carried out to stabilize the soil with Vitrified Polish Waste (VPW) as an admixture and geogrid provision. The VPW is mixed in proportions of 5%, 10%, 15%, 20% to virgin soil and the engineering and index properties of soil are evaluated after stabilization. The subgrade soil is also tested for simulated traffic loading condition by providing geogrid membrane in the laboratory and result analysis proved that VPW has a good potential to be used as an additive for black cotton soil stabilization

Key words: Black cotton soil, Expansive soil, Vitrified Polish Waste, Geogrid, Stabilization, Subgrade, Traffic.

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1. INTRODUCTION

Pavement development is going on at a rapid pace in India. The need for good sustainable and safe pavements is an accepted criterion these days, as most of the pavements performance depends upon subgrade of pavement. Subgrade is the major load carrying layer of pavement, hence it should be necessarily checked that it has desirable properties to bear the designed

traffic. Otherwise, the life span and the performance of the pavement gets gradually deteriorated.

The studies carried on deformation causes of pavement (Sharad.S.Adlinge and Prof.Ankit Gupta, 2004) mainly showed that the reason was majorly due to weak subgrade which is because of presence of weak soils which cannot take the design load. Considering this criteria, black cotton soils are in prime need for stabilization as they are present in major portion of India. Their engineering properties are to be enhanced by necessary stabilization techniques. Investigations on large scale were carried out for various pavement subgrade soils such as black cotton soils, marine clays, and soft soils by using various additives (Biswas Gourhari et al., 2010) such as fly ash (Baiwara Ramlakhan et al 2013) lime (Kunal Anand et al., 2013; Nadgouda. K.A and Hegde. R.A, 2010) rice husk ash (Dr. D. Koteswara Rao et al., 2012) etc.

Along with these traditional methods, stabilization of such soils were recently done by usage of bio- enzymes such as Renolith, Terra-Zyme which also proved to be environmental friendly. Hence usage of different waste materials produced by industries for the improvement of weak soil properties can be performed which reduces the problem of their disposal and also adds to the strength and safety of structures. Along with this stabilization, usage of geo synthetics (Prateek Malik and Nikhil Verma, 2015) such as geo polymers or geo textiles (Dr.P.Senthil Kumar and R.Raj Kumar, 2012) or geogrids (Sarika B.Dhule and S.S.Valunekar, 2011) as a reinforcing layer will improve the strength of the subgrade with weak soils such as black cotton soils and soft clays. Here vitrified polish waste is a solid waste generated from tiles manufacturing process this is also causing a great deal of disposal problems Since it has specific pozzolanic properties, this waste can be utilized as a stabilizing material for weak soils such as marine clays (Dr. D. Koteswara Rao, 2013) soft soils and also in soil-cement (K. Purnanandam et al., 2013) and concrete stabilization (M.T.S Lakshmayya and G. Aditya, 2017), here in this study stabilization technique is adapted by usage of vitrified polish waste for expansive subgrade soil. Optimum dosage of VPW addition is found by conducting various tests confining to standards of Indian soil testing codes (IS 2720-3-1 (1980), (IS 2720-4 (1985), (IS 2720-8 (1983), (IS 2720-16 (1987), (IS 2720-40 (1977), (IS 2720 Part 20-(1992), (IS 2720- Part 10- (1991) and then in addition to this geo grid usage is also done to impart additional strength. Later loading testing is done for stabilized soil for design traffic loading according to the standards of Indian road congress (IRC: 37-2012, 2010).

1.1. Study Area

Samalkot – Uppada road is an important road in East Godavari District as it connects number of towns and villages with state and national highways. Widening of this road is done from Km 6/0 to Km13/0 by filling the subgrade with selective fills, here the problem is encountered with expansive soils and hence following investigations are made

2. MATERIAL SPECIFICATIONS

The material that is used for stabilization here is vitrified polish waste (VPW). It is the wastage obtained from manufacturing process of vitrified tiles, which is causing a huge disposal problem. Effective utilization of this waste in process like stabilization also helps in environmental safeguarding. The chemical properties are discussed below, along with black cotton soil properties and properties of geo grid that is used as separation layer between sub grade and sub base layer.

2.1. Properties of VPW

Table 1 Properties of VPW

Oxide composition	Percentage %
SiO ₂	49.52
Al ₂ O ₃	14.70
CaO	1.40
Fe ₂ O ₃	0.40
MgO	2.45
Na ₂ O	2.71
K ₂ O	2.69
P ₂ O ₅	0.05

2.2. Properties of Black Cotton Soils

The properties of black cotton soil used in the investigation is mentioned below after carrying out engineering and index properties tests in laboratory following IS codal specifications

Table 2 Properties of Black Cotton Soil Used

Property	Value
Colour of soil	Black
Specific gravity	2.56
Liquid limit	39.9%
Plastic limit	15.56%
Plasticity index	24.34
Maximum dry density g/cc	1.7
Optimum moisture content	17.13%
Soaked C.B.R	2.1
Unsoaked C.B.R	2.88
U.C.S (Kn/m ²) @ O.M.C	198.27
Free swell index	23%
Natural moisture content	28.12%
Coefficient of uniformity Cu	3.18
Coefficient of curvature Cc	0.14
Permeability cm/s	7.1*10 ⁻⁵
Shrinkage limit	18.2%
Swelling pressure	1.2kg/cm ²

The above specified are the properties of black cotton soils and VPW. After stabilizing, soil with VPW, geo grid is used to enhance the strength of layers and placed as a separator between sub base and base and cyclic plate load testing is carried out.

2.3. Geo grid Details

The geo grids used in the experimental investigation are manufactured from carefully selected grades of high density polyethylene HDPE. In this investigation uni-axial geo grid is used. It is used in many engineering and industrial applications, where long service life and excellent durability is required often under adverse conditions. It is mainly used for reinforcing weak

soils and embankments etc. The durability and life of structure prolonged because of its usage.

2.4. Test Procedure

The various laboratory tests of the virgin expansive soil and its combination with varying proportions of VPW is conducted following the codal specifications mentioned in Table 3

Table 3 IS Codes Followed in Investigation

Test	Code Followed
Grain size analysis	IS 2720 (part IV) 1985
Atterberg limits	IS 2720 (part V) 1985
Proctor test	IS 2720 (part VII) 1983
C.B.R test	IS: 2720 (part - 16)-1979
Linear shrinkage	IS 2720 (part 20) 1992
U.C.S test	IS 2720 (part 40)1977
Flexible pavement design	IRC: 37-2012, 2010.
Free swell index	IS 2720 (part 40)1977

3. EXPERIMENTAL INVESTIGATION AND RESULTS DISCUSSION

The major aim of the study is to attain an optimum dosage of VPW for stabilizing black cotton soils, for which many preliminary investigations on virgin soil, VPW and mixes with combinations of virgin soil and VPW in various proportions is carried out. The tests include Atterberg limits testing, compaction testing, CBR and cyclic plate load testing with inclusion of geo grid. By all the above experimental investigations optimum VPW content is found at 15% and results are furnished as follows.

3.1. Atterberg Limits

The Atterberg limits tests are performed for virgin clay, VPW and clay with varying proportions of VPW content. The results are analyzed, it is very clear from the Table 4 that with the liquid limit decreased gradually and the plastic limit increased accordingly with increase in VPW content. The test results of Atterberg limits are as shown below, along with index property testing, the engineering properties are thoroughly tested which are discussed in coming sections.

Table 4 Atterberg Limits of Soil with Varying VPW Content

% Mix	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)
100% Soil	39.9	15.56	24.34
95% Soil + 5% VPW	35	17.84	16.16
90% Soil + 10% VPW	34	19.07	13.93
85% Soil + 15% VPW	33	19.31	13.69
80% Soil + 20% VPW	29.5	19.33	10.17

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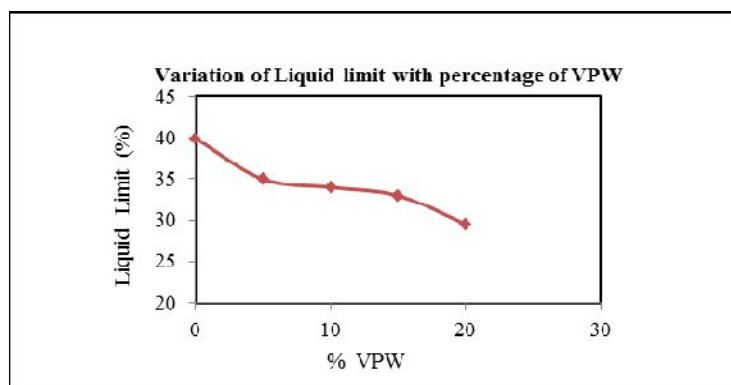


Figure 1 Variation of Liquid Limit with % of VPW

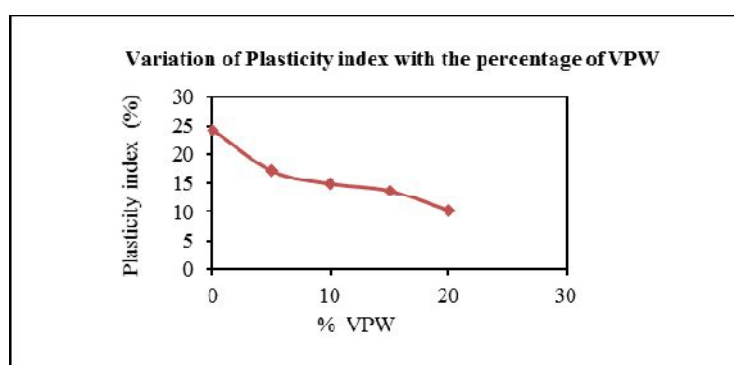


Figure 2 Variation of Plasticity Index with % of VPW

3.2. Moisture Content Test

The determination of water content black cotton soil on mixing with various proportions of VPW is carried out by dry oven method following the code (IS 2720-Part II 1973). The moisture content attained is expressed in terms of % oven dry weight. This is represented in Table 5 below, a decrease in moisture content with increase in VPW content is observed

Table 5 Moisture Content Details of Mixes

M.C	0% VPW	5% VPW	10% VPW	15% VPW
1 st day	28.12%	27.15%	25.04%	23.21%
7 th day	26.12%	24.24%	21.27%	19.07%
28 th day	12.34	11.15	10.06	9.15

3.3. Free Swell Index (FSI)

The free swell index of black cotton soil determined along with varying VPW content following the codal specification is 2720- part 40- 1977 and the results are tabulated below. From Table 6 it is clearly evident that there is a considerable decrease in swelling with increase in VPW content until 15% addition

Table 6 Free Swell Index Results

FSI	Mix Proportion	BC	BC+5% VPW	BC+10 %VPW	BC+15 % VPW	BC+20 %VPW
1	Initial Volume (ml)	10	10	10	10	10
2	Final volume(ml)	12.3	12.05	11.85	11.6	11.7
3	FSI	23%	20.5%	18.5%	16%	17%

3.4. Linear Shrinkage Test

The linear shrinkage limit test on black cotton soil and optimum of VPW addition is performed following the code IS 2720 (Part 20)-1992 and results are tabulated in Table 7, a decrease in linear shrinkage is observed with an increase in VPW content

Table 7 Linear Shrinkage Details

Mix proportion	Shrinkage % (Avg of trails)
BCS	24
BC+5 % VPW	15
BC+10% VPW	12
BC+15% VPW	8

3.5. Grain Size Distribution

Sieve analysis is performed on VPW which is used for stabilization and particle size distribution analysis is made. The coefficient of uniformity (c_u) and coefficient of curvature (c_c) values for the admixture is found to be 3.18 and 0.14 respectively. They can be understood with Fig 3.

Table 8 Grain Size Distribution of VPW

Sieve size	Weight of VPW retained	Cumulative weight of VPW retained	%VPW retained	%Passing
4.75	5	5	1.000	99.000
2.36	5	10	2.000	98.000
1.18	15	25	5.000	95.000
0.6	5	30	6.000	94.000
0.46	10	40	8.000	92.000
0.3	235	275	55.000	45.000
0.15	135	410	82.000	18.000
0.075	80	490	98.000	2.000
Pan	10	500	100.000	0.000

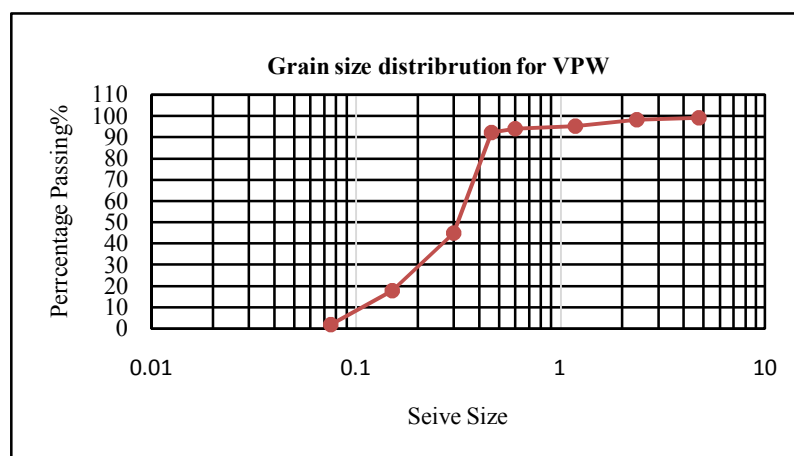


Figure 3 Graph Plotted to show VPW Grain Size Distribution

3.6. Proctor Compaction Testing

Proctor compaction is performed for virgin clay and with varying VPW content. Optimum moisture content (OMC) and maximum dry density (MDD) for each combination is

determined. It is analyzed from results that with increase in VPW up to 15%, MDD increased and after that MDD started decreasing to a lower value. The OMC of the mixes decreased compared to virgin soil, it is also assed that up to 15%, voids are filled by VPW and the results are portrayed in Table 9.

Table 9 Variation of dry density and moisture with Varying VPW

% Mix of VPW	Maximum dry density (g/cc)	Optimum moisture content (%)
100% Soil+ 0% VPW	1.7	17.13
0% Soil+ 100% VPW	1.32	21.25
95% Soil + 5% VPW	1.90	11.95
90% Soil + 10% VPW	1.92	12.8
85% Soil + 15% VPW	1.94	12.4
80% Soil + 20% VPW	1.93	12.0

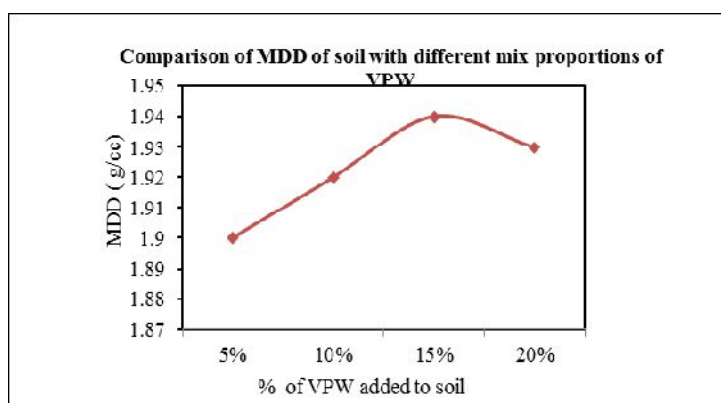


Figure 4 Comparison of MDD with Varying Proportions of VPW

3.7. CBR Testing

The OMC and MDD is attained from the compaction test and both soaked and un soaked CBR tests are conducted on virgin soil, VPW and black cotton soil with varying contents of VPW. The soaked CBR test is conducted by soaking CBR mould in water for 4 days for fully saturated condition, and it is found from experimental observation that soaked CBR value is more than un soaked CBR value from 15% of VPW mix. This is majorly because of the presence of Cao which gains strength on curing, soaked CBR value increased from 2.1% to 10% @15% VPW mix and further decreases. The results are shown in Table 10.

Table 10 Variation of Soaked and Unsoaked CBR with Varying VPW

% Mix	Soaked C.B.R (%)	Unsoaked C.B.R (%)
100% Soil	2.1	2.88
100% VPW	7.29	36.09
95% Soil + 5% VPW	5.49	6.82
90% Soil + 10% VPW	7.07	16.69
85% Soil + 15% VPW	10	8.87
80% Soil + 20% VPW	8.27	8.12

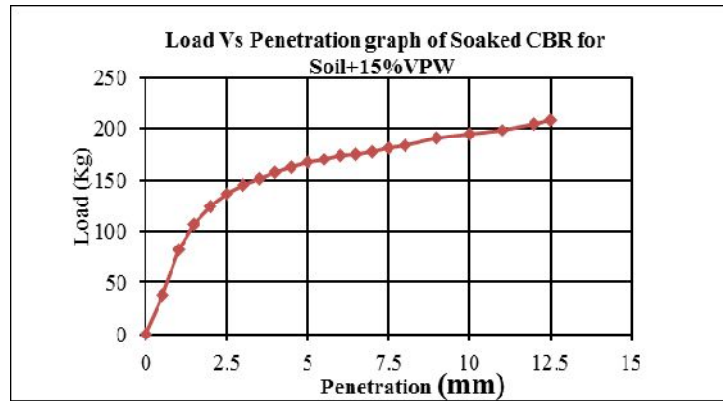


Figure 5 Load Vs Penetration Graph of Soaked CBR for 15% VPW addition

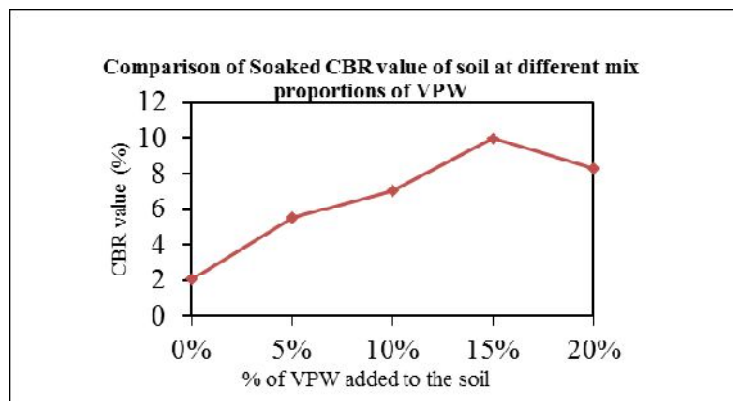


Figure 6 Comparison of Soaked CBR for Varying VPW Mix Proportions

3.8. Unconfined Compressive Strength Test

Cylindrical specimens of expansive soil taken is prepared along with VPW replacements in regular increments to calculate the unconfined compressive strength, then the load per unit area of cylindrical specimens at their failure is calculated following the standard codal specifications IS 2720- Part X 1991 and the results are tabulated in Table 11. The test is conducted at 7 days and it is observed that the compressive load carrying capacity is increased @15% replacement of VPW

Table 11 UCS Test Results

Sl. No	Mix of soil	U.C.S (Kn/m ²) 7day
1	BCS	198.27
2	BCS+5% VPW	207.19
3	BCS+10% VPW	218.38
4	BCS+15% VPW	236.46
5	BCS+20% VPW	228.12

3.9. Cyclic Plate Load Testing

Cyclic plate load testing is performed on untreated soil with 15% VPW, and with 15 % VPW with geo grid reinforcement between layers of soil. In cyclic loading test, model tank of circular shape with 500 mm dia and 470 mm height is used and proceeded. The settlements

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reduced from untreated soil to soil with treated subgrade and geo grid reinforcement as shown in Table 12.

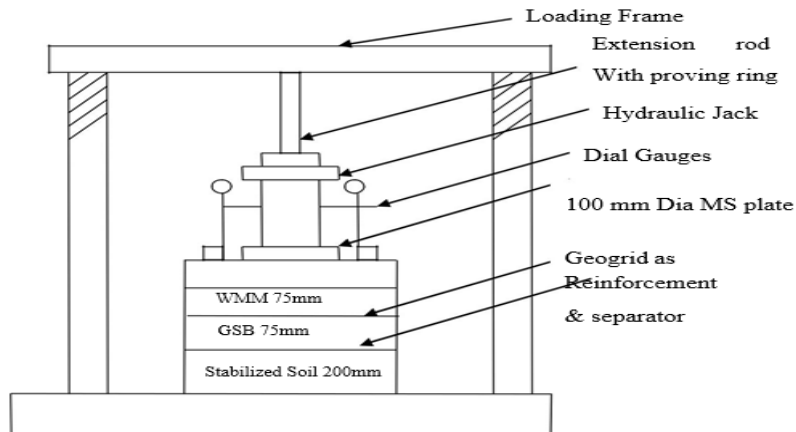


Figure 7 Experimental Set-Up for Cyclic Plate Load Testing

Table 12 Cyclic Plate Load Test Results

Type of subgrade	Sub base course	Base course	Ultimate ² load(kN/m) OMC	Settlement (mm) OMC
Untreated Black cotton soil	-	-	630	16.78
Treated Black cotton soil with 15% VPW	-	-	1512	15.49
Treated soil with 15% VPW and Geogrid provided as reinforcement & separator	GSB	WMM	3229	14.12

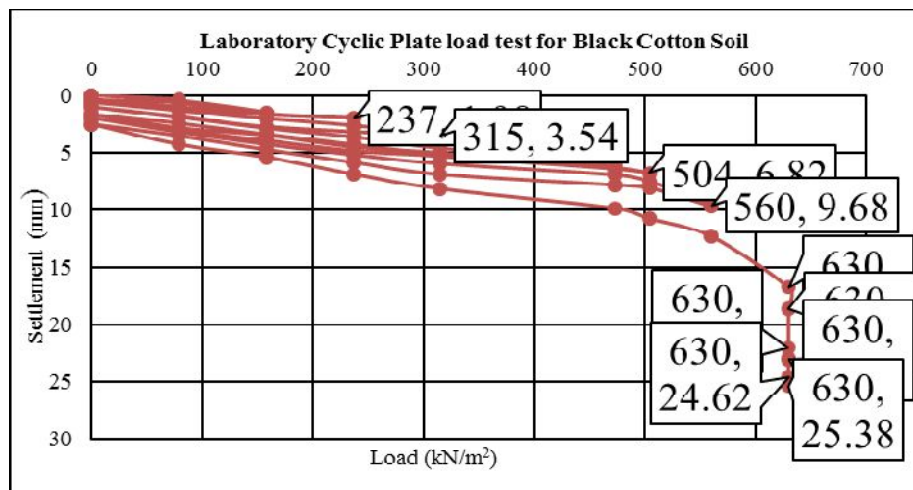


Figure 8 Cyclic Plate Load Test Results for Black Cotton Soils

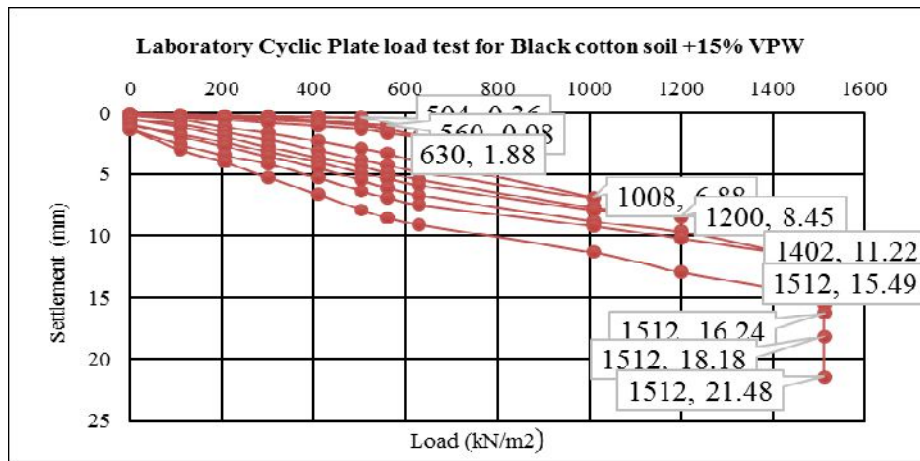


Figure 9 Cyclic Plate Load Test Results for Black Cotton Soils+15%VPW

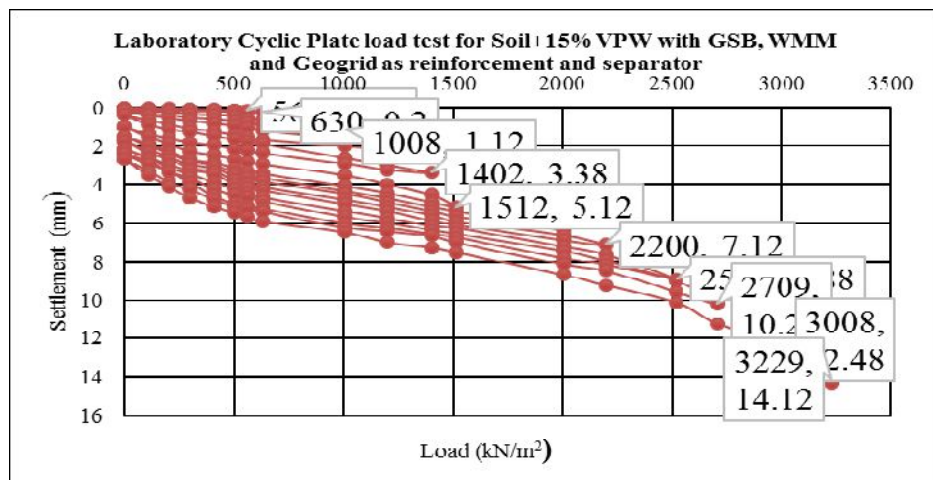


Figure 10 Cyclic Plate Load Test Results for Black Cotton Soils+15%VPW with GSB, WMM and Geogrid

Then loading testing is performed and analysed according to pavement loading conditions of IRC 37:2001, According to IRC 37:2001, maximum laden weight coming on a vehicle is 44 tonnes. Hence in cyclic loading, the results are compared @560kN/m² and settlements attained are shown in Figure 11.

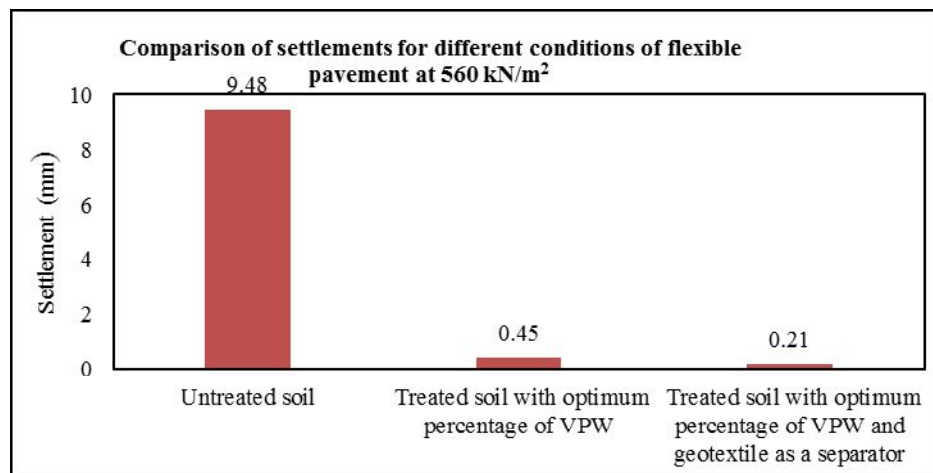


Figure 11 Comparison of Settlements for Different Conditions of Flexible Pavements

4. THICKNESS REDUCTION AFTER STABILIZATION

The design traffic and pavement thickness calculation made according to IRC 37:2001 guidelines, according to that

- No of commercial vehicles taken per day=8800
- $N=365 * [(1+r)^x - 1] * r * A * D * F$
- N=number of cumulative standard axles according to design
- A=initial traffic in terms of CVPD
- D=lane distribution factor=0.5 for single lane carriage way
- F=vehicle damage factor=4.5
- R=annual growth rate =10%
- $A = P * (1+r)^x = 8800 * (1+0.1)^1 = 9680$
- $N = 365 * [(1+0.1)^5 - 1] * 0.1 * 9680 * 0.5 * 4.5 = 48569400 = 48.57 \text{ msa} = 50 \text{ msa}$

Now Since the No. of years between the last count and the year of completion of construction is taken as two and half year and designed for a period of 10 years according to IRC: 37-2012 as the construction of road is in progress. Then

- $A = P * (1+r)^x = 8800 * (1+0.1)^{2.5} = 11168.$
- $N = 365 * [(1+0.1)^{10} - 1] * 0.1 * 11168 * 0.5 * 4.5 = 146173596 = 146.17 \text{ msa} = 150 \text{ msa}$

The CBR value of untreated soil is found to be 2% and the thickness of pavement calculated from plate 2 of IRC 37 is found out to be 925 mm and 975 mm for 50 and 150 msa respectively

Table 13 Pavement Thickness and Composition Detailing from IRC

CBR 2%				
Cumulative Traffic(msa)	Total Pavement Thickness(mm)	Pavement Composition		Granular base & sub base(mm)
		Bituminous Surfacing		
		BC(mm)	DBM(mm)	
10	850	40	100	Base=250
20	880	40	130	
30	900	40	150	
50	925	40	175	Sub-base=460
100	955	50	195	
150	975	50	215	

After the stabilization process with VPW, the optimum admixture content is found to be 15% and at this optimum content of admixture, CBR value is found out to be 10 %. For this CBR value from IRC 37:2001, the thickness for pavement calculated for 50 and 150 msa is found out to be 585 mm and 625 mm respectively.

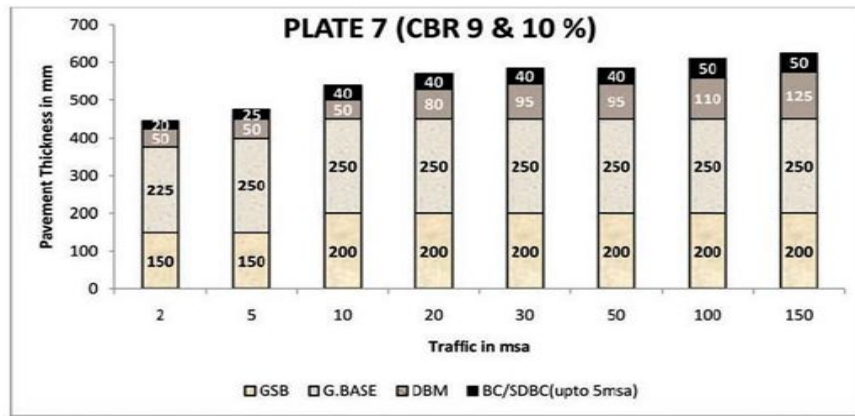


Figure 12 Plate 7 of IRC 37:2012 Design Standards for Flexible Pavements

Hence from above calculations it is very clear that a considerable reduction in pavement thickness i.e. 340 mm and 350 mm is achieved for the traffic of 50, 150 msa thereby reduction in pavement cost is also attained hence it can be concluded that the usage of VPW as additive and geo grid reinforcement is both economical and strength improver from the above experimental investigation

5. CONCLUSIONS

The following are the major conclusions drawn from this experimental investigation

- The design traffic of Samalkot - Uppada road is 50 msa and 150 msa respectively for 5 and 10 years.
- It can be concluded from moisture content test that there is a decrease in moisture content with increase in proportion of VPW content, with increase in number of days this reduction in moisture content increases even more, this is mainly because of water absorbing nature of VPW, the moisture content decreases by 25.8% for 15% replacement of VPW when compared with ordinary clayey soil on 28th day.
- From free swell index test it can be concluded that the expansion of black cotton soil is moderate and it is further reduced because of the addition of VPW, hence there is a considerable decrease in soil swelling because of VPW addition and hence VPW can be considered as good stabilizer to reduce swelling and effective at 15% addition.
- From the linear shrinkage analysis, it can be concluded that the replacement of soil by stabilizer VPW reduced linear shrinkage considerably from 24% to 8%.
- The Optimum proportion of VPW with soil is found to be 15% through CBR test. (With MDD as 1.94 g/cc)
- The Liquid limit and Plasticity index of the soil is reduced by 17.29% and 43.76% at optimum proportion of VPW.
- Soaked CBR value increased by 5 times for treated soil when compared to untreated soil.
- From the test results of U.C.S it is clearly evident that the compressive strength carrying capacity of soil specimens increased because of the stabilization with VPW hence VPW replacement for expansive soils is effective and most suitable at 15% replacement
- The thickness of the pavement is reduced by 340 mm i.e., from 925 mm for untreated soil to 585mm for treated soil at a design traffic of 50 msa and the thickness of the pavement is reduced by 350 mm i.e., from 975 mm for untreated soil to 625 mm for treated soil at a design traffic of 150 msa.

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- The load carrying capacity of the subgrade is improved by 2.4 times when stabilized it with optimum proportion of VPW.
- The improved flexible pavement i.e., Black cotton Soil+15% VPW with GSB, WMM and Geogrid at OMC, can carry 560 kN/m² with a settlement of 0.15mm, which is further in elastic limits.
- For a settlement of 2 mm the load carrying capacity of Black cotton Soil+15% VPW with GSB, WMM and Geogrid at OMC, can carry a load of 1200 kN/m² which is in allowable limits.

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- [22] IRC: SP 37-1991, "*Guidelines for evaluation of load carrying capacity of bridges*".
- [23] IRC: 37-2012, "*Guidelines for the Design of the Flexible pavement*".